52. IWK

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FACULTY OF COMPUTER SCIENCE AND AUTOMATION

COMPUTER SCIENCE MEETS AUTOMATION

VOLUME II

Session 6 - Environmental Systems: Management and Optimisation

Session 7 - New Methods and Technologies for Medicine and Biology

Session 8 - Embedded System Design and Application

Session 9 - Image Processing, Image Analysis and Computer Vision

Session 10 - Mobile Communications

Session 11 - Education in Computer Science and Automation

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Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.

Professor Peter Scharff
Rector, TU Ilmenau

Professor Christoph Ament
Head of Organisation

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52nd Internationales Wissenschaftliches Kolloquium
Technische Universität Ilmenau
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N. Buyankhishing, K. Masumoto, M. Aley

Parameter estimation of an unconfined aquifer of the Tuul River basin Mongolia

INTRODUCTION

Population growth in the Ulaanbaatar area, Mongolia has been rapid, and demand for potable water will continue to rise. The water requirements of Ulaanbaatar city are generally met from groundwater originating from the Tuul River. Groundwater use in the area has consistently increased since 1960. 274.56 thousand m^3/day groundwater supplies in the area derived from alluvial deposit. Totally, there are 159 production wells for the water supply in Ulaanbaatar city. Averagely about 110-130 production wells work and pump 150 000 m^3/day water [1]. Central extraction system has been working since 60's, groundwater level (22-25m) in the area is declined and created depression cone that indicates groundwater shortage. The reliability of predictions using groundwater models depends on parameter estimation.

Study Area

The study area is situated in the Ulaanbaatar city area (Fig 1). The Ulaanbaatar area is located in the Tuul River basin, which is surrounded by mountains. The mountains in the south have general altitude 2000 m above sea level, and the highest peak is 2256.3 m a.s.l. The north side of these mountains has sharp edges, which range in elevation from 600 to 900 m above sea level, and forms several parallel valleys. The Tuul River originates in the Hentii Mountains and flows generally from northeast to southwest in a variably meandering channel. The total length of the Tuul River is 819 km, and the total catchment area is 50.4 km^2. The catchment area near Ulaanbaatar is about 6300 km^2. The width of the river in the city area is 45-50 m, but during dry season falls to 5-18 m. River depth during droughts is about 0.9-1.2 m, average velocity is 0.31-2.24 m/sec and maximum velocity reaches 4 m/sec. The river is recharged mainly by precipitation (JICA, 1995). Daily mean discharge data has collected at the Ulaanbaatar station from 1946 to 1991, with values ranging from 0 m^3/sec (winter time) to 627 m^3/sec (during flooding). The river at Ulaanbaatar is completely frozen from December to February. Flow gradually begins in March and discharge gradually increases to peak in the rainy seasons from July to August. River water levels during flooding are typically 1.8-2.0 m higher than in drought periods. The study area is characterized by a semi-arid climate, with a hot, dry summer and cold winter. Average monthly temperature in the river basin varies from a minimum of –2.3^{o}C in January to maximum of 16.7^{o}C in August, as recorded at Ulaanbaatar station. Annual precipitation in the area varies from 242.7 mm to 396.7 mm, depending on the altitude of the station sites. Nearly 80 percent of annual precipitation falls between October and March.

Hydrogeological Setting

Geologically, geology around the study area consists mainly of Carboniferous sediments, which are intruded by Jurassic to Triassic granitoids rocks and locally covered by Cretaceous sediments

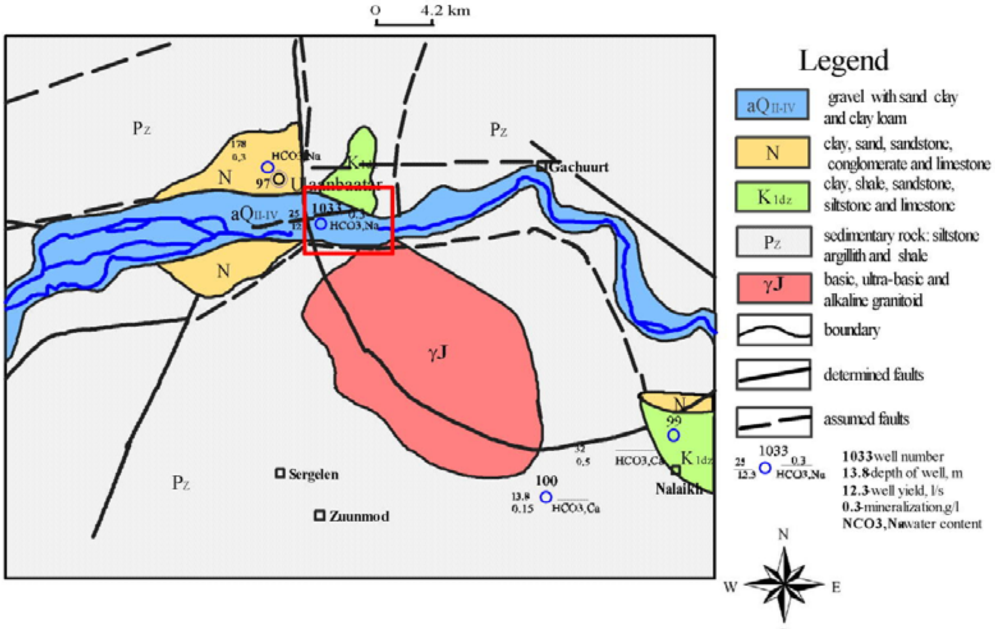

Figure 1. Study area

are contained in the Paleozoic to Quaternary formations. The geologic units are further classified into hydrogeologic units depending on hydraulic and storage properties of the rocks. Broad alluvial basin has been filled by more than 5-65m of gravel with sand and clay and it is commonly irregular in thickness and composition. Average thickness is 30m. The alluvial deposits are divided into two layers: upper (Later Quaternary) and lower (Middle to Later Quaternary). Upper coarse-grained deposit makes up the most permeable zones of the unconfined aquifer system. Hydraulic property data for the alluvium-unconfined aquifer was derived from aquifer pumping tests. Hydraulic conductivities of coarse-grained alluvium in the upper layer range from 44 to 55 m/day; however, values of 100 m/day are more typical. Specific yield ranges 0.13 to 0.2. Lower finer-grained alluvium, it is typically a fine sand with silt and clay and has hydraulic conductivity values of about 5 to 35 m/day. Depth to groundwater from monitoring wells varies in the range 0-11m below ground level. The water table is 0- m below land surface in the basin.

Boundary condition

The bottom of the unconfined aquifer system is defined, as the top of Tertiary clay is a low-permeability unit that does not store or transmit significant quantities of groundwater. This is considered as no-flow boundary condition in the numerical model. The northern and southern boundaries of the alluvium are bounded by Carboniferous sedimentary and Jurassic granite. These boundaries are considered as no-flow boundaries. The western and eastern parts constant flux boundary condition is chosen because groundwater flows from west to east. Source of data accumulated from previous researchers.

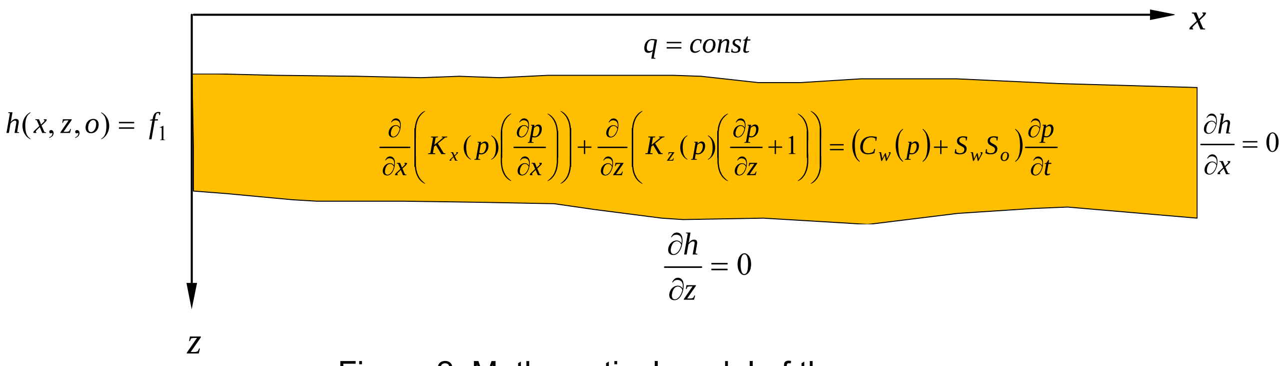

Figure 2. Mathematical model of the area

Grid design
All the grids have uniform lateral dimensions of 50 m by 50 m. The model grid covering km2 of the study area was descretised into 238 cells with 37rows and 7 columns and vertically by two layers (Fig 2). The cell is irregularly spaced.

Input Parameters
The lower layer is defined by material of relatively low- permeability between upper layer and impermeable layer. Upper zone of lower layer consists of fine gravel and finer sand that is yellowish-gray in color, fine grained, and with clay. Thickness of this zone is 1-4m. Below this zone is sand with fine gravel and clay. Thickness of this zone is 1-4m. Third zone is same as first zone of the lower layer. Thickness ranges 2-5m.

Calibration
The conceptual model is converted to a numerical representation of the system for simulation using the groundwater flow code '3-D unsaturated flow' (Masumoto K, 1997). Calibrations are performed by systematically varying parameters within reasonable ranges and investigating the effects of these changes on the results. Errors between measured and simulated heads are minimized during the calibration.

Results from the steady-state model can easily be used as initial conditions in the transient model. For our case we used transient simulation model. First need to estimate steady-state time duration. We developed the steady-state model for aquifer conditions of November 1976. The head at that time was chosen because the water levels were near equilibrium.
Thus, the steady-state model was used to investigate initial conditions (steady-state time), hydraulic conductivity and recharge rate.

The inverse problem must be solved to find appropriate model structure and model parameters, and then solve the forward problem to obtain required prediction results. The inverse problem or calibration involves adjustment of the model structure and model parameters of a simulation model simultaneously or sequentially so as to take the input-output relation of the model fit any observed excitation-response relation of the real system.

The calibration targets of the study were:
- To minimize errors between measured and simulated water levels in

November.

- To find head distribution between observation points.
- To estimate initial conditions.
- To estimate recharge rate and hydraulic conductivities.
- In trial-and-error calibration, parameter values are initially assigned to each grid.
- During calibration, parameter values are adjusted in sequential model runs to match simulated heads to the calibration targets

Firstly we developed an initial condition (steady-state time) appropriate for November 1976. To develop this initial condition, we run the transient simulation model using the recharge rate. The first guess of the recharge rate was zero, derived from meteorological observation data. The study area belongs to a semi-arid region, in which evaporation largely exceeds precipitation. Hydraulic conductivity was assumed as 0.01cm/sec.

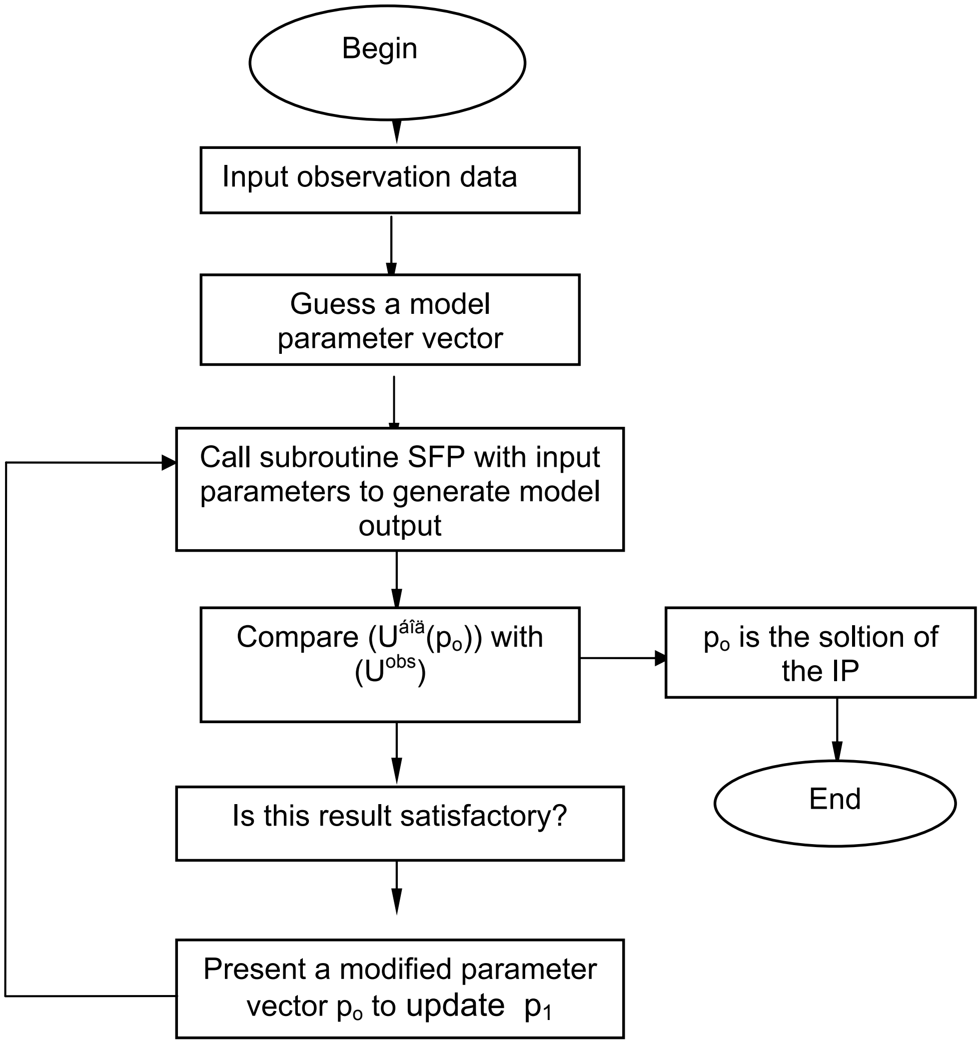

Figure 3. Flow chart of the trial and error method

State variables of a groundwater system can be easily measured. This measurement, such as water level, is usually obtained from observation wells. Water levels are used for the study, but the accuracy of the result depends on the accuracy of the information and the magnitude and distribution of the aquifer permeability. About 50 simulations were made in order to obtain a set of recharge rate and hydraulic conductivities. Recharge is not only highly dependent on climate, but also on surface and subsurface conditions. We estimated 25 hydraulic conductivities.

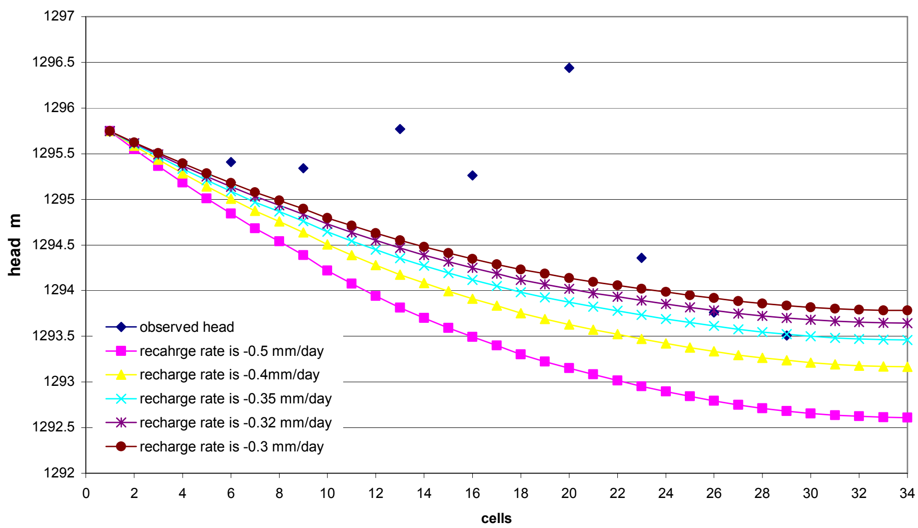

Figure 4. Estimation of recharge rate

Heads after 6 months was chosen as an initial condition because that stable condition continues until April. This time period belongs to winter season.

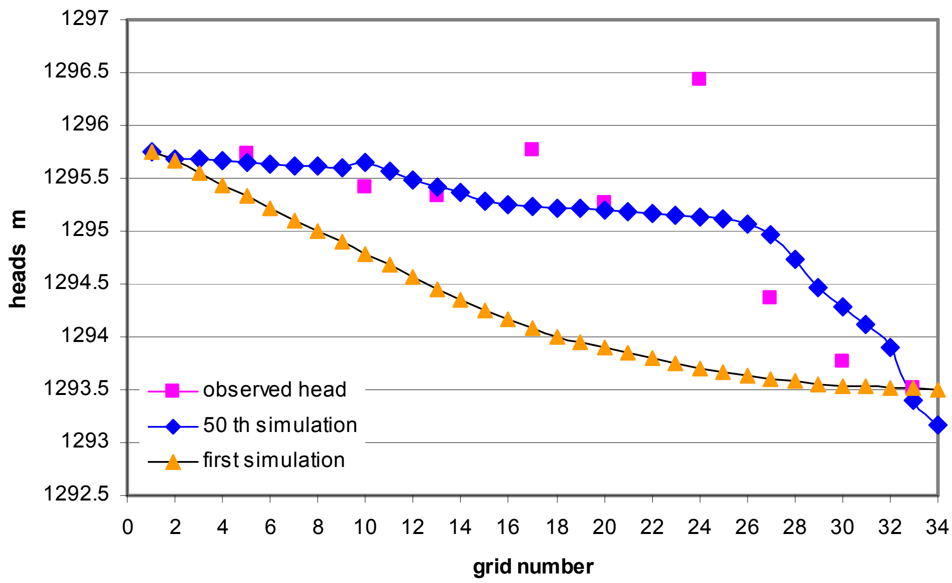

Figure 5. Estimation of hydraulic conductivity

Then we got calibrated recharge rate. Result was compared with meteorological data. Calibrated recharge rate was –2.9 mm/day. We also tested heads after 3 months, and recharge difference was 0.3.

After the 50th simulation, the simulated heads were close to the observed ones. The calibrated hydraulic conductivity is show in Fig 5.
About 50 simulations were made in order to obtain a set of recharge rate and

hydraulic conductivities. Each simulation, simulated heads were compared with observed heads were adjusted to minimize head difference. The final set of model hydraulic conductivity provided “best fit” between observed and simulated heads. Calibrated heads almost similar to the observed head.

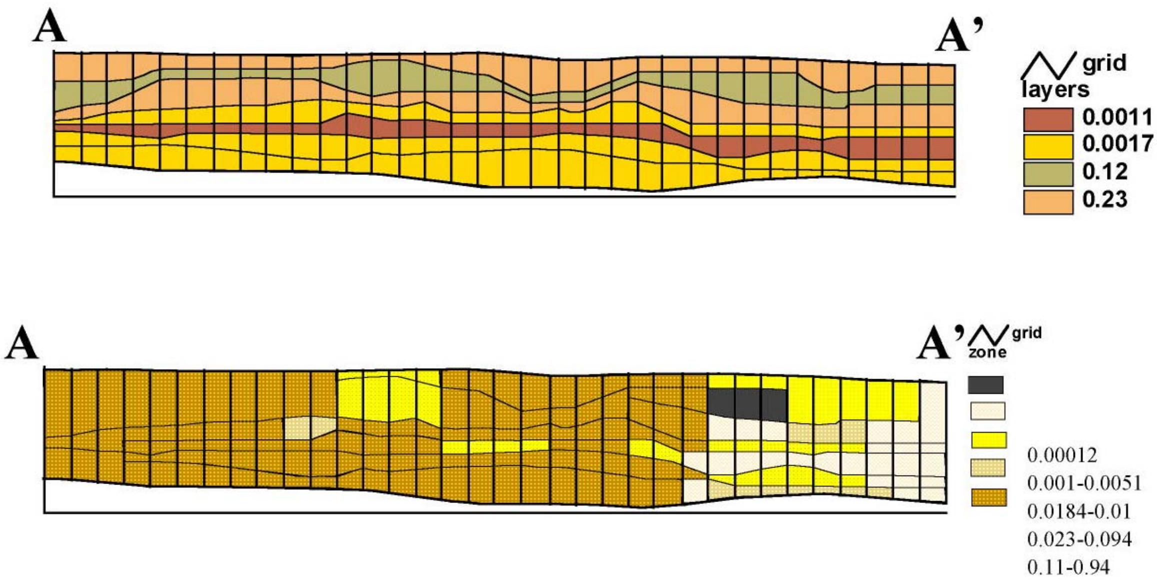

Figure 6. Comparison of initial and calibrated hydraulic conductivity

For this study we used water-level information, but the accuracy of the result depends on the accuracy of the information and the magnitude and distribution of the aquifer permeability.

Recharge is not only highly dependent on climate, but also on surface and sub-surface conditions.

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